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November 01, 2004

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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Re: ENSC 340 Project Design Specification for a Venipuncture Site Locator (Teeka)

Dear Dr. Rawicz:

Attached you will find the *Teb Medical Inc.*'s *Design Specification* for a venipuncture site detector. This document lists the design specifications for our ENSC 340 project. Our goal is to design a cost effective and practical device to locate a suitable site for venipuncture.

We are in the process of designing and building a device, Teeka, to improve tedious and painful circumstances in locating veins. Teeka collects data by using an infrared laser transmitter and detector, processes the data with a microprocessor, and finally locates the best venipuncture site.

Group members will be using this document as a reference for design. The group is comprised of four students: Ameneh Atai, Amir Goldan, Ida khodami, and myself. Should you have any questions or concerns regarding this document, please contact us via email, ensc340-vein@sfu.ca.

Sincerely,

Balraj Mattu
Balraj Mattu
Chief Executive Officer
Teb Medical Inc.

Enclosure: *ENSC 340 Project Design Specification for a Venipuncture Site Locator*

Design Specification for a Venipuncture Site Locator

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Submitted to: Dr. Andrew Rawicz, Mr. Steve Whitmore, Mr. Mike Joerdsma, and Mr. Scott Logie
School of Engineering Science
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Date: November 01, 2004

Executive Summary

The majority of the general population has never experienced a problem walking into a medical clinic to get a blood test. Nevertheless, some individuals that have various physical conditions – obesity, cancer, and drug addictions to name a few, go through excruciating pain if a proper venipuncture site cannot be located by the doctor or nurse taking the test.

Teb Medical Inc.'s (TMI) goal is to research and develop an accurate, safe, and inexpensive device that will allow doctors and nurses to locate a venipuncture site on any patient quickly and effortlessly. The trauma some patients go through in this procedure can therefore be reduced or even eliminated. TMI plans to build a versatile laser based device that will carry out this task.

Since there is no product like this on the market to date, TMI intends to globally distribute this product wherever venipuncture is performed including: hospitals, clinics, offices, etc. With the project low cost of this device, TMI intends to supply these institutions with large quantities of the device.

In the first phase of the development process TMI plans to create a prototype of the venipuncture site locator. The prototype will be able to transmit and receive modulated pulsating infrared beams using two adjacent reflective object sensors, compare the result of the two sensors, process the difference and locate the vein detection site. Phase one is scheduled for completion in mid December, 2004.

In the second phase of the development process TMI will be developing a production model of the venipuncture site locator. Phase two will be contingent on the result of the prototype, which would give a clear indication of the feasibility and effectiveness of the device.

Table of Contents

List of Figures

1 Introduction

The purpose of this document is to record the Design Specifications for the venipuncture site locator. Everything in this document is subject to change and/or refinement during the development process. The purpose for the venipuncture site locator device is to accurately locate the appropriate vein when the operator is unable to do so. The task of developing such a device is divided into three stages: the signal transmission stage (transmitter), the signal retrieval stage (detector), and the signal processing stage (processor).

1.1 Acronyms

BPF	Band Pass Filter
LPF	Low Pass Filter
LED	Light Emitting Diode
LCD	Liquid Crystal Display
A/D	Analog to Digital
C/V	Current to Voltage

1.2 Referenced Documents

[1] Design specification for an MP3 to Audio Gateway. The Audio Group.

[2] Proposal for a Venipuncture Site Locator

1.3 Intended Audience

This document is intended to be a design guideline for engineers within TMI developing the prototype of the venipuncture site locator (Teeka). The project manager will use this document to measure project performance, develop objectives, and verify the project design. Marketing personnel will use this document to develop initial promotional material.

2 System Overview

The presence of the ambient light is the major source of error in our detection process, that's why we have to make sure the output signal of the phototransistor is resulted from the incident near-infrared photons only. Knowing the fact that the ambient light adds a dc offset to our output signal, we have decided to transmit a ~20 kHz modulated pulsating beam using an infrared LED.

In the signal retrieval stage, after performing current to voltage conversion, we pass the received signal through a high order bandpass filter tuned to the carrier frequency (~20 kHz in our case). This way the detector's sensitivity to stray light is dramatically reduced. The last step to be performed in this stage is to extract the useful date which is imposed on the carrier wave through downshifting with a demodulator.

In the signal processing stage, we digitize the analog signal and perform our vein-detection algorithm using a microcontroller. If a vein is detected, the LED will turn on or a beeper will start beeping. Other useful information is displayed on an LCD for testing purposes only.

The system block diagram is shown in Figure 2-1.

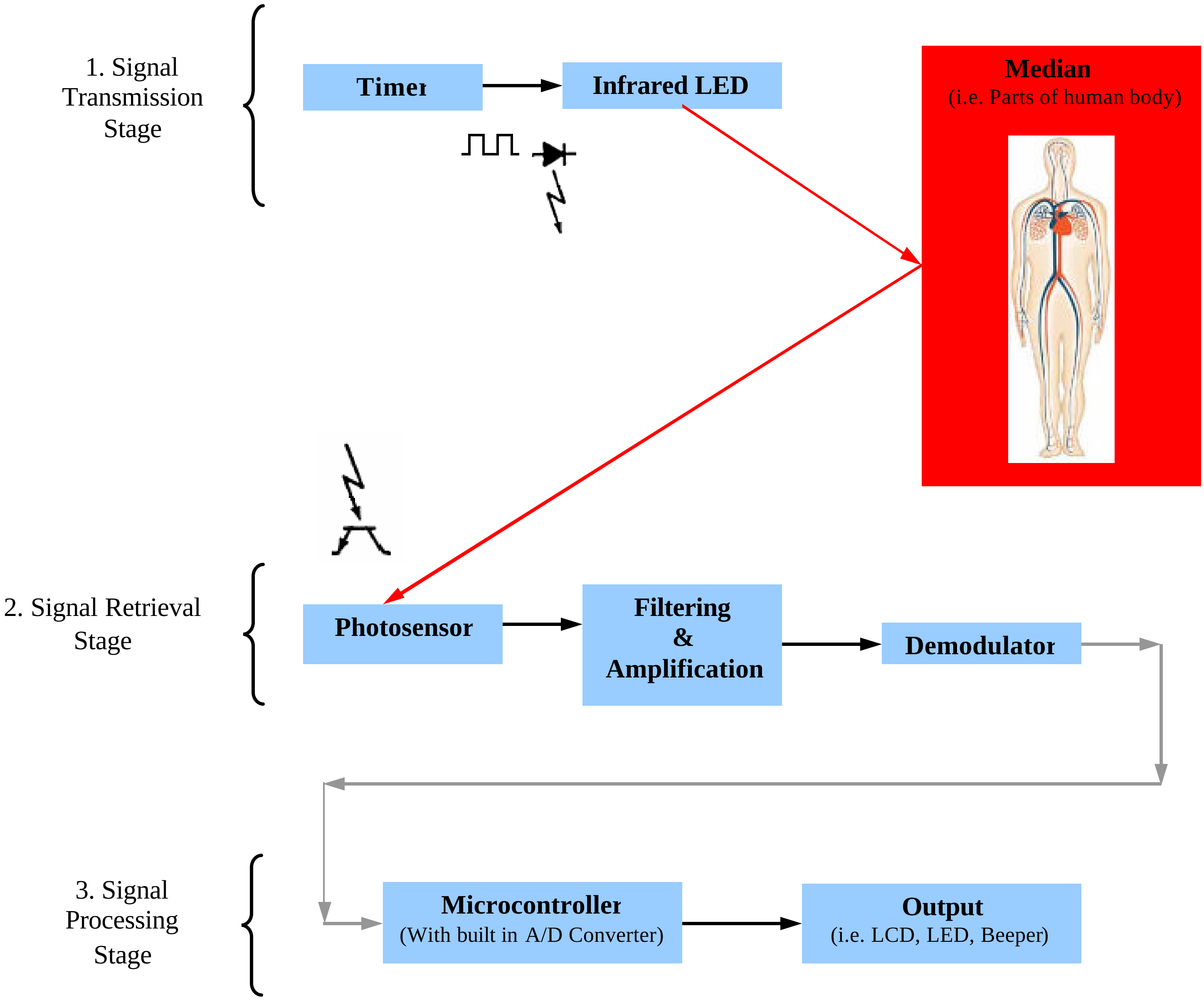

Figure 2-1, System Overview

3 System Hardware

TMI employs two adjacent reflective object sensors which require two identical receiver circuits. The output signal from each receiver is amplified, filtered, and downshifted from the carrier frequency using a demodulator. The output of the demodulators is then passed to the microprocessor for digital signal processing. This section describes the design specification for the signal transmission, signal retrieval and signal processing stages.

3.1 Signal Transmission Stage

The transmission stage is shown in Figure 3-1.

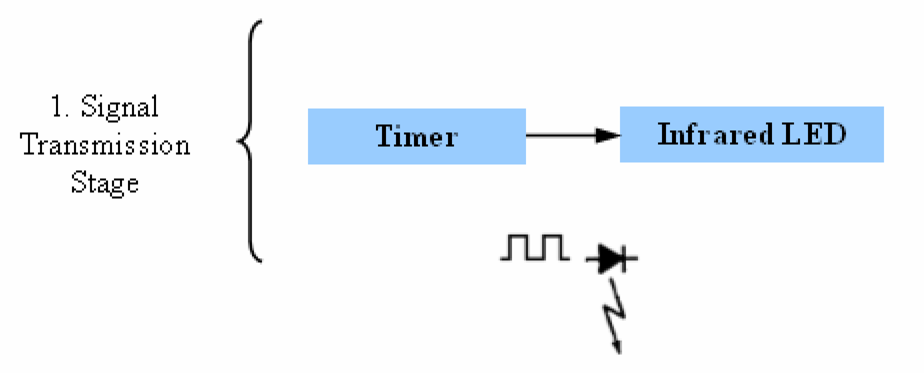

Figure 3-1, The signal transmission stage.

The transmitter is comprised of one 555 timer and two infrared LEDs. The 555 timer is required to transmit a 20 kHz modulated pulsating beam using an infrared LED.

TMI has chosen OPB742W for the reflective object sensor. As shown in Figure 3-2, the photosensor responds to radiation from the emitter only when a reflective object passes within 0.3 inches (or 0.75 cm) of the sensor. This characteristic of the OPB742W is highly desirable since it severely restricts the field of view of the sensor.

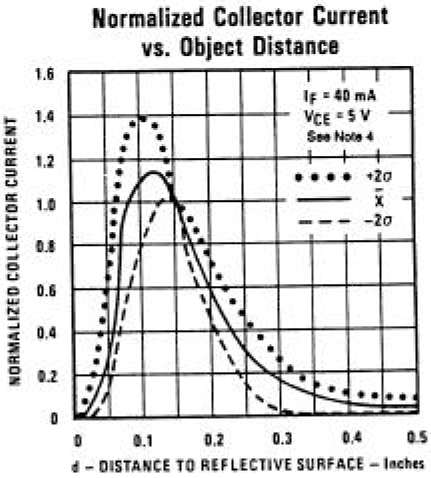

Figure 3-2, Normalized collector current VS. object Distance

For the purpose of vein detection, the above feature of OPB742W will eliminate the need to calculate the depth of the vein with respect to the surface of the skin.

Note that the period of the modulated pulsating infrared beam should exceed the rise and fall time of the OPB742W phototransistor as shown in Figure 3-3. We have chosen the value of the load resistor to be 100 ohms which corresponds to a rise and fall time of approximately equal to 5us.

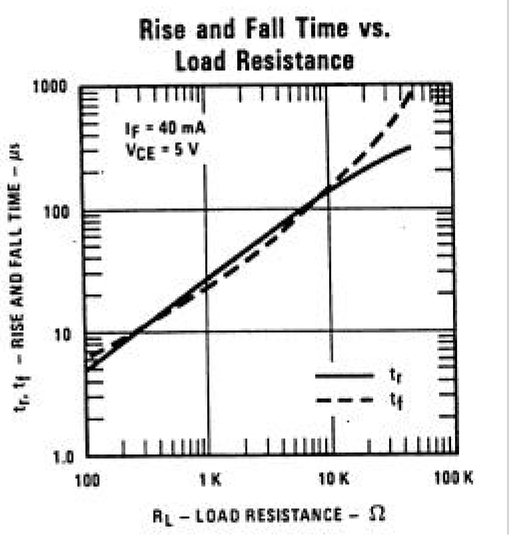

Figure 3-3, Rise and Fall Time Vs Load Resistor

Choosing 20 kHz for the frequency of the timer, the period is calculated to be 50µs which exceeds the minimum requirement of 5µs.

3.2 Signal Retrieval Stage

The block diagram of the signal retrieval stage is illustrated in Figure 3-4:

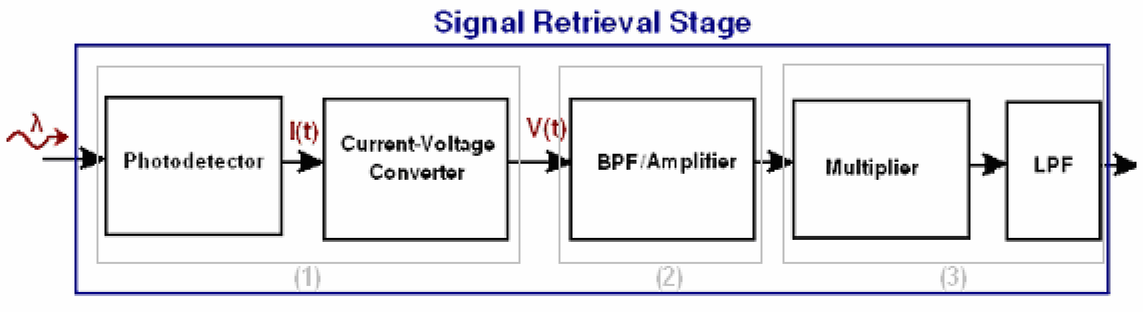

Figure 3-4, The signal retrieval stage.

For simplicity the signal retrieval stage is divided into three main stages: photo-detection, filtering/amplification, and demodulation. Note that the retrieval stage is performed twice.

3.2.1 Photo-detection

The photo-detection block diagram, as shown in Figure 3-5, consists of two stages, namely the photodetector and a current-to-voltage converter. As mentioned previously in section 3.1, TMI has chosen OPB742W, a reflective object sensor which includes both the LED laser and a silicon photodetector.

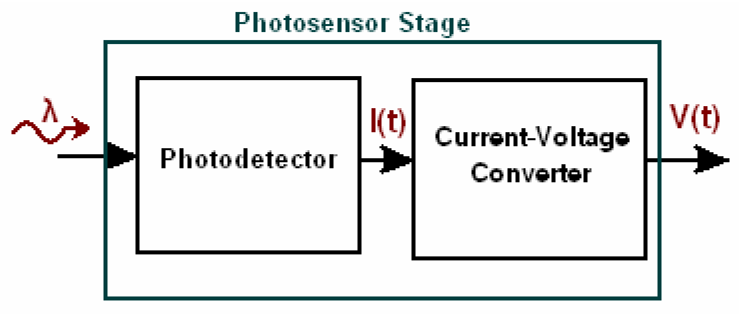

Figure 3-5, The photo-detection block diagram.

The emitter-collector voltage of OPB742W is required to be equal to or higher than 5V for the photo-transistor to be in active mode.[1] Maximum collector current in OPB742W is 100µA which results in a negligible collector voltage across the load resistance (R_L = 100? [2]) allowing emitter voltage of as low as 5V. However, the emitter voltage for the prototype circuit has been chosen to be 15V in order to match the upper rail voltage of the op-amps utilized in the amplification and demodulation circuit. Furthermore, a voltage buffer is required to prevent loading effects of the next stage.

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[1] See OPB742W datasheet in Appendix C.

[2] See section 3.1.

3.2.2 Filtering and Amplification

The filtering and amplification block diagram is illustrated in Figure 3-6.

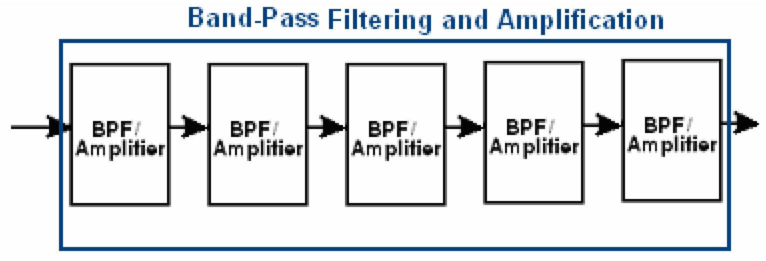

Figure 3-6, The filtering and amplification circuit.

The circuit includes five identical band-pass filtering and amplification stages. Five stage filtering results in a fifth order band-pass filter, with 100dB/dec rejection slope, and corner frequencies of approximately 10 KHz and 30 KHz. The overall configuration filters high and low frequencies and passes the desired signal with a frequency of approximately 20 KHz. Furthermore, amplification in each stage reduces loading effects while providing a total mid-band gain required for further analysis of the signal.

3.2.3 Demodulator

The demodulator block diagram is demonstrated in Figure 3-7.

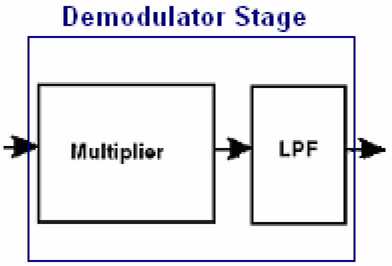

Figure 3-7, The demodulator block diagram.

The demodulator circuit consists of a multiplier and a fourth order low-pass filter. The easy to use, and low cost multiplier chosen for this application is MPY634, an accurate laser trimmed four-quadrant multiplier. MPY364 is employed to demodulate the signal through multiplying it by a 20 KHz signal; the same signal used to modulate the LED's input signal. The resulting output signal is connected to a fourth order low-pass filter with lower cut-off frequency of 10Hz.

4 Signal Processing Stage

Once the two signals are received from the demodulators, they must be compared to each other to determine whether a vein is present. To accomplish this comparison, two operations are necessary, which are analog to digital (A/D) conversion and digital processing. The OOPIC microcontroller module has been chosen to perform both of these tasks for the prototype design as it is a completely programmable microcontroller with a built in A/D converter.

4.1 Analog to Digital Converter

The OOPIC microcontroller has 32 programmable I/O ports. Two of the programmable ports are used as analog input pins and one of the programmable ports is used for the digital output signal, which indicates whether a vein is detected. By choosing the A/D to be 12 bits, we can ensure a small latency in the conversion and very high precision in detecting changes in both the received signals. High precision is a crucial element in this stage.

4.2 Microprocessor Stage

Once the digitized values from each of the received signals are processed, a vein detection algorithm will determine whether or not a vein is present. The algorithm that will be programmed into the OOPIC is shown in Figure 4-1.

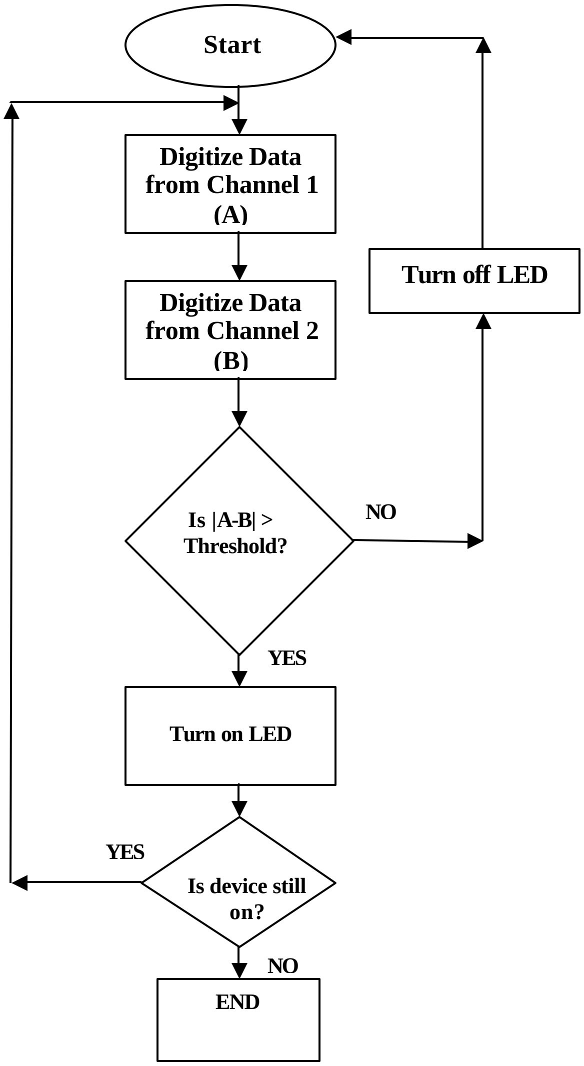

Figure 4-1, The microcontroller algorithm

As outlined in the above diagram, the OOPIC processor inputs both of the demodulator channels, converts them to digital values, then compares the difference in the values to a programmable threshold, which indicates whether a vein is present. The threshold value is determined through the testing process. The two phototransistors will only have a difference in reflection when a vein is present underneath one and not the other, hence a vein is detected. At this point, a signal is sent to the OOPIC's output port and the LED is turned on.

5 Test Plan

Test plan outlines the approach undertaken by the members of TMI toward the function and integration testing of the venipuncture site locator. It lays out common scenarios that the system will undergo and shows the expected results given the described test conditions. This test plan is not a definitive guideline for testing the system and in not meant to limit ad hoc testing in anyway.

5.1 Test Cases

TMI uses the bottom-up methodology to test the functionality of the system.

5.1.1 Transmitter Test (TT01)

Overview: The following tests shall be run to make sure that the transmitter is emitting a pulsating infrared beam.

Objective: To check the functionality of the 555 timer together with the OPB742 infrared LED.

Pre-Condition(s): The transmitter circuit shall be built according to the schematic provided to the tester shown in Appendix A.

Post-Condition(s): A pulsating infrared beam is successfully emitted.

Step	Test Conditions	Expected Results	Pass?

1	Supply is provided to the transmitter circuit and the output of the 555 timer (node TT.1[3]) is probed.	A square-wave with a frequency of 20 kHz and peak-to-peak voltage approximately equal to the supply voltage.
2	The input voltage at the anode of the OPB742 LED (node TT.2) is probed.	A square wave with a frequency of 20 kHz and peak-to-peak voltage not exceeding 1.7V.

Variation(s): None

Note(s): The reason that the infrared beam is modulated is to eliminate the contribution of the ambient light, which is a major source of error in our detection mechanism.

5.1.2 Detector Test (DT01)

Overview: The following test shall be run to ensure the detection of infrared photons only.

Objective: To check the functionality of the OPB742 phototransistor, the 5th order bandpass filter, the multiplier, and the 4th order low-pass filter.

Pre-Condition(s): The detector circuit shall be built according to the schematic provided to the tester shown in Appendix A.

Post-Condition(s): A successful detection of the intensity of the reflected infrared photons.

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[3] Look at the schematic in Appendix A for the appropriate node

Step	Test Conditions	Expected Results	Pass?
1	The output of the 5th order band-pass filter (node DT.1) is probed. I. No reflective surface shall be within the OPB742 sensor's filed of view. [4]	Zero volts.	
2	II. A reflective surface is placed within 0.3 inches of the OPB742 phototransistor.	A 20 kHz wave with a fix peak-to-peak voltage.	
3	III. The same reflective surface used in part II is moved back and forth in front of the OPB742 phototransistor within a rang of 0.5 inches.	A 20 kHz wave with a changing peak-to-peak voltage as the reflective surface is moved closer to or away from the OPB742 sensor.	
4	The output of the demodulator (node DT.2) is probed. I. No reflective surface shall be within the OPB742 sensor's filed of view.	Zero Volts.	
5	II. A reflective surface is placed within 0.3 inches of the OPB742 phototransistor.	A downshifted DC signal with its magnitude equal to the intensity of the reflected infrared photons.	
6	III. The same reflective surface used in part II is moved back and forth in front of the OPB742 phototransistor within a rang of 0.5 inches.	A DC signal with a changing magnitude as the reflective surface is moved closer to or away from the OPB742 sensor.	

Variation(s): Ideally, when no reflective surface is present within the OPB742 sensor's filed of view, the output voltage of the BPF must be zero but due to input-referred noise voltages and coupling effect, the output voltage will be approximately zero. The coupling

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[4] Refer to Appendix B for datasheet of OPB742, where "the field of view" is defined.

effect can be minimized if the value of the high-pass resistor R_{HP} is chosen to be as small as possible, and eliminated if the circuit is shielded properly.

Note(s): The output voltage of the C/V converter is in the range of a few millivolts; therefore, we are not capable of testing the functionality of the OPB742 phototransistor directly. A successful reading at the output of the band-pass filter validates the functionality of the OPB742 phototransistor and the C/V converter.

5.1.3 Processor Test (PT01)

Overview: The analog outputs of the demodulators are inputs to the OOPIC microprocessor. After running the vein detection algorithm, the digitized values are displayed on the screen.

Objective: To check the functionality of the OOPIC microprocessor

Pre-Condition(s): The analog outputs of the demodulators are interfaced with the OOPIC microprocessor through two analog input channels.

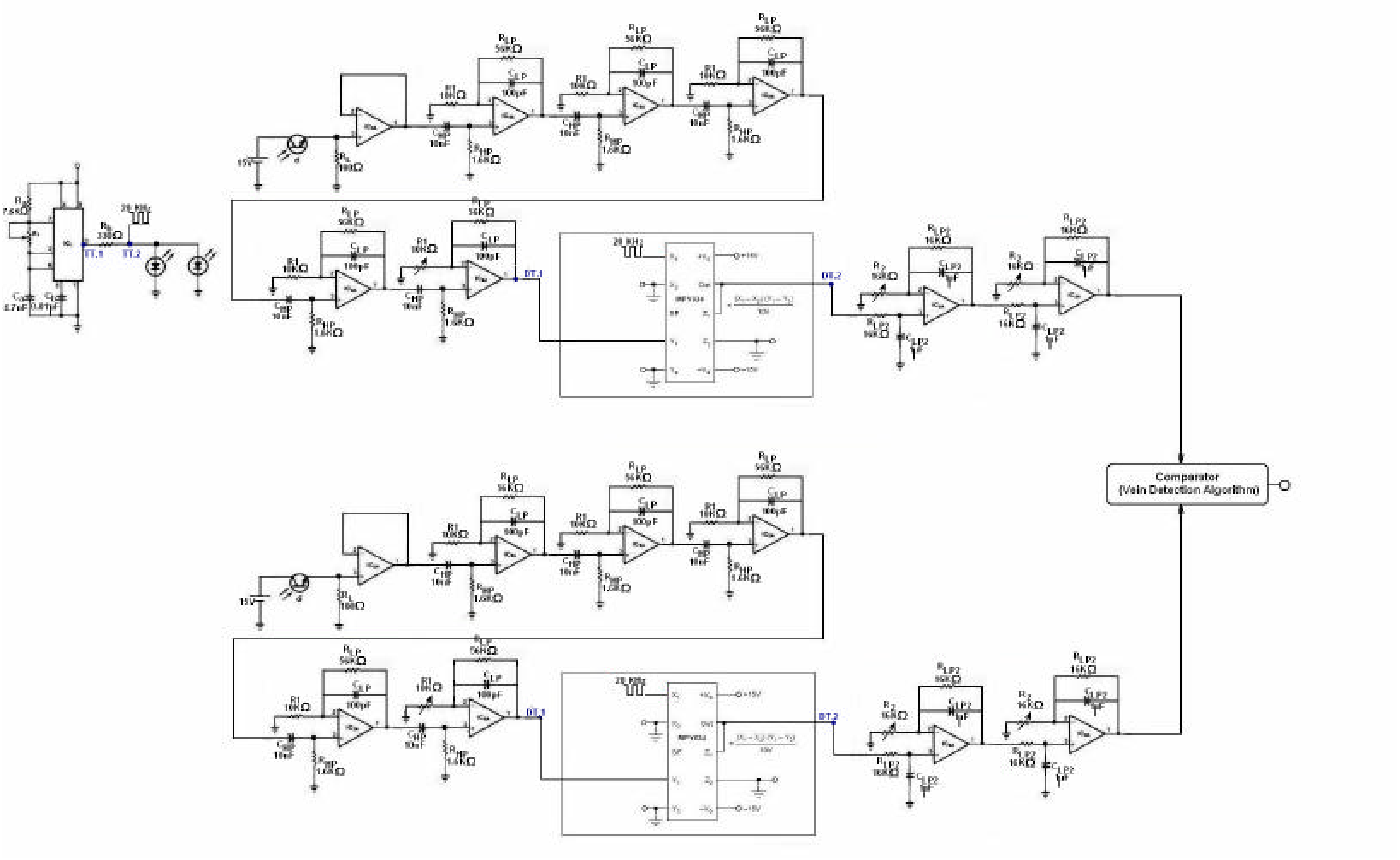
Post-Condition(s): Two digitized value corresponding to the two analog outputs of the demodulators.

Step	Test Conditions	Expected Results	Pass?
1	An analog signal is fed through one of the channels that interface with the OOPIC A/D converter. The digitized value is displayed on the screen.	A value corresponding to the analog input signal.	
2	Increase the magnitude of the analog signal.	An increasing value	
	Decrease the magnitude of the analog signal.	A decreasing value	

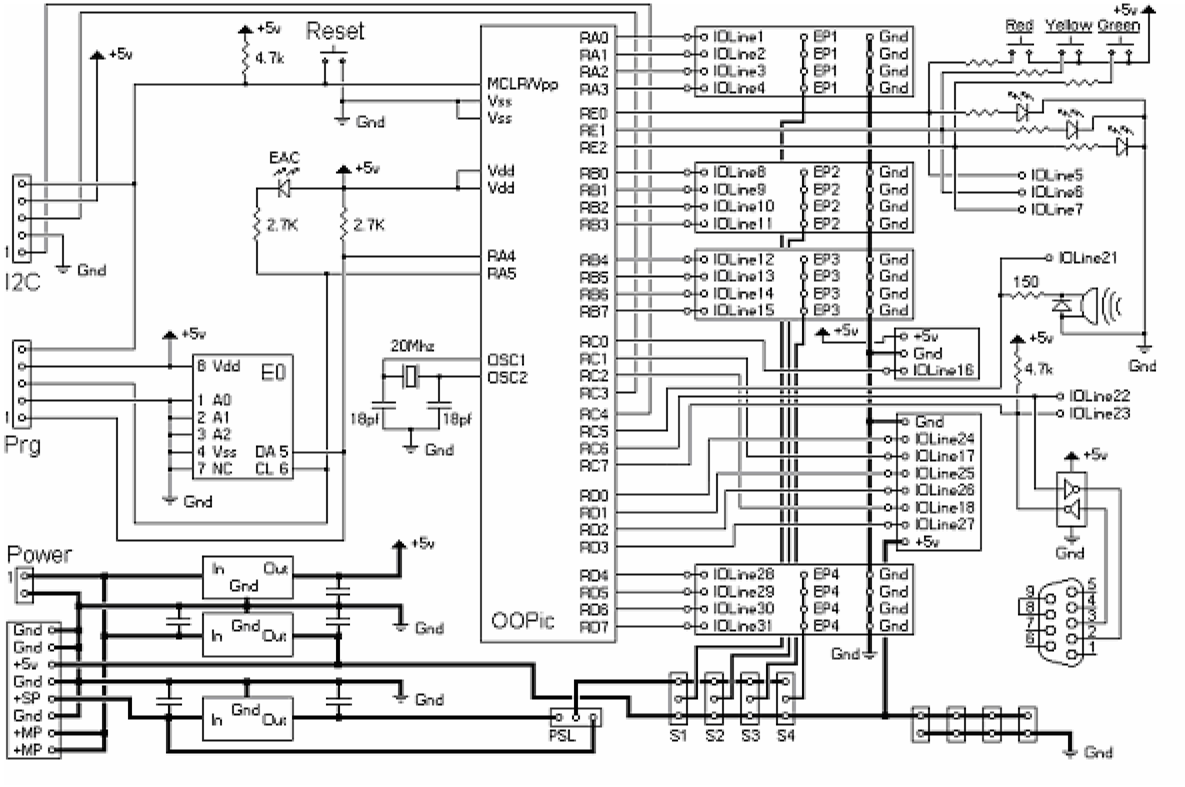
Variation(s): None

Note(s): None

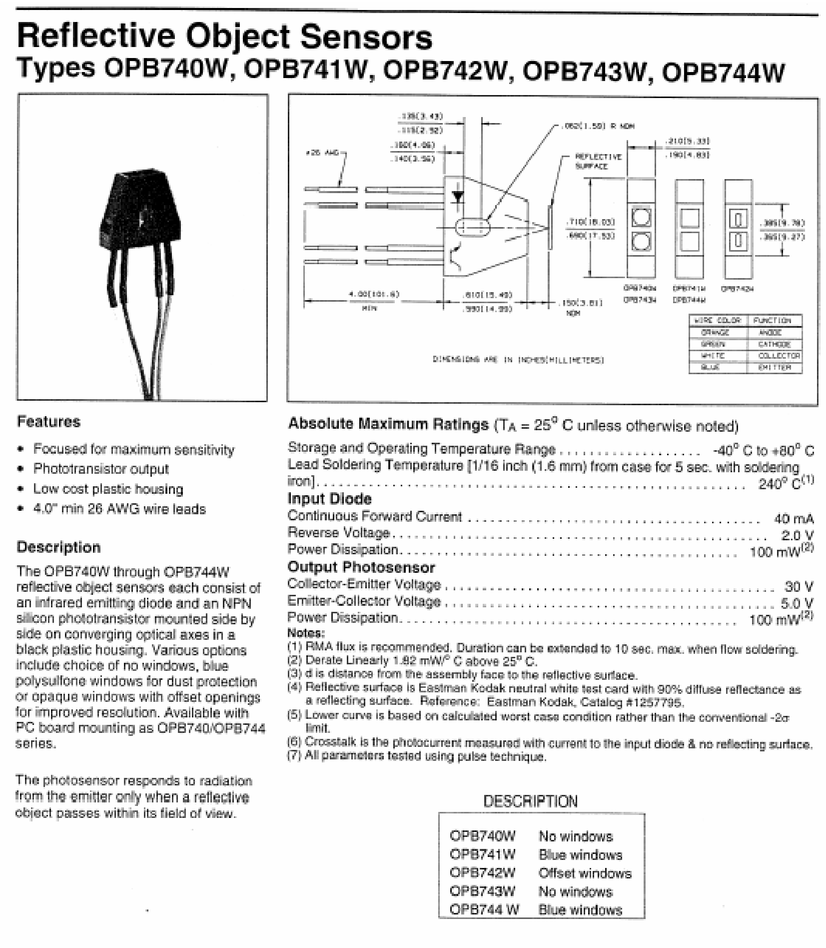
Appendix A – Circuit Schematic



Appendix B – OOPIC Schematic



Appendix C – OPB742W Data Sheet



Reflective Object Sensors
Types OPB740W, OPB741W, OPB742W, OPB743W, OPB744W

WIRE COLOR	FUNCTION
ORANGE	ANODE
GREEN	CATHODE
WHITE	COLLECTOR
BLUE	EMITTER

Features

- Focused for maximum sensitivity
- Phototransistor output
- Low cost plastic housing
- 4.0" min 26 AWG wire leads

Description

The OPB740W through OPB744W reflective object sensors each consist of an infrared emitting diode and an NPN silicon phototransistor mounted side by side on converging optical axes in a black plastic housing. Various options include choice of no windows, blue polysulfone windows for dust protection or opaque windows with offset openings for improved resolution. Available with PC board mounting as OPB740/OPB744 series.

The photosensor responds to radiation from the emitter only when a reflective object passes within its field of view.

Absolute Maximum Ratings ($T_A = 25^{\circ}$ C unless otherwise noted)

Storage and Operating Temperature Range . . . . -40° C to +80° C
Lead Soldering Temperature [1/16 inch (1.6 mm) from case for 5 sec. with soldering iron] . . . . 240° C(1)

Input Diode

Continuous Forward Current . . . . 40 mA
Reverse Voltage . . . . 2.0 V
Power Dissipation . . . . 100 mW(2)

Output Photosensor

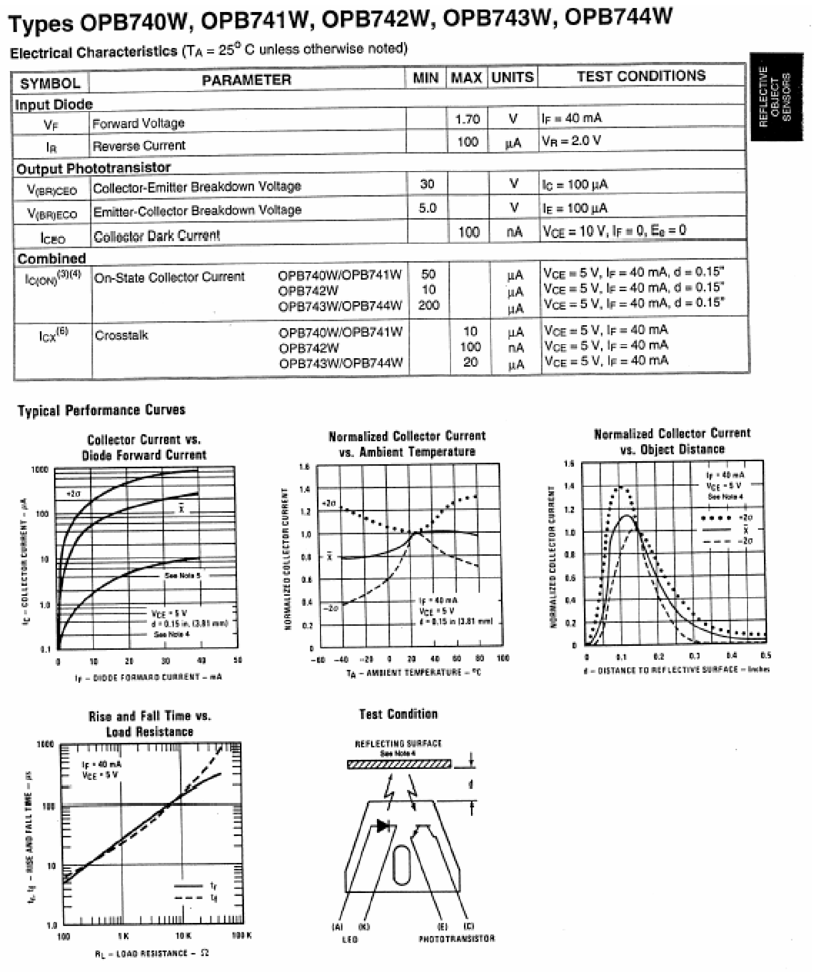
Collector-Emitter Voltage . . . . 30 V
Emitter-Collector Voltage . . . . 5.0 V
Power Dissipation . . . . 100 mW(2)

Notes:

(1) RMA flux is recommended. Duration can be extended to 10 sec. max. when flow soldering.
(2) Derate Linearly 1.82 mW/° C above 25° C.
(3) d is distance from the assembly face to the reflective surface.
(4) Reflective surface is Eastman Kodak neutral white test card with 90% diffuse reflectance as a reflecting surface. Reference: Eastman Kodak, Catalog #1257795.
(5) Lower curve is based on calculated worst case condition rather than the conventional -2σ limit.
(6) Crosstalk is the photocurrent measured with current to the input diode & no reflecting surface.
(7) All parameters tested using pulse technique.

DESCRIPTION

OPB740W	No windows
OPB741W	Blue windows
OPB742W	Offset windows
OPB743W	No windows
OPB744 W	Blue windows



Types OPB740W, OPB741W, OPB742W, OPB743W, OPB744W

Electrical Characteristics ($T_A = 25^{\circ}$ C unless otherwise noted)

REFLECTIVE OBJECT SENSORS

SYMBOL	PARAMETER		MIN	MAX	UNITS	TEST CONDITIONS
Input Diode						
V_F	Forward Voltage			1.70	V	$I_F = 40$ mA
I_R	Reverse Current			100	µA	$V_R = 2.0$ V
Output Phototransistor						
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage		30		V	$I_C = 100$ µA
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage		5.0		V	$I_E = 100$ µA
I_{CEO}	Collector Dark Current			100	nA	$V_{CE} = 10$ V, $I_F = 0$, $E_e = 0$
Combined						
$I_{C(ON)}$(3)(4)	On-State Collector Current	OPB740W/OPB741W OPB742W OPB743W/OPB744W	50 10 200		µA µA µA	$V_{CE} = 5$ V, $I_F = 40$ mA, d = 0.15" $V_{CE} = 5$ V, $I_F = 40$ mA, d = 0.15" $V_{CE} = 5$ V, $I_F = 40$ mA, d = 0.15"
I_{CX}(6)	Crosstalk	OPB740W/OPB741W OPB742W OPB743W/OPB744W		10 100 20	µA nA µA	$V_{CE} = 5$ V, $I_F = 40$ mA $V_{CE} = 5$ V, $I_F = 40$ mA $V_{CE} = 5$ V, $I_F = 40$ mA

Typical Performance Curves

Collector Current vs. Diode Forward Current

Normalized Collector Current vs. Ambient Temperature

Normalized Collector Current vs. Object Distance

Rise and Fall Time vs. Load Resistance

Test Condition